The Evolution of Bright Infrared Galaxies

IRAS – Launch date January 25, 1983

Halloween, 2003

Stony Brook Open Night
“Normal” massive galaxy types – elliptical & spiral galaxies

- Elliptical
  - Bulge of old stars
  - Large black hole
  - Very little gas & dust

- Spiral
  - Bulge of old stars + large black hole
  - Disk of young stars & gas
Infrared emission

- Stars are very hot & emit the most energy in the visible
- People are warm & emit the most energy at 10 microns
- Dust in galaxies is cool-to-warm & emit the most energy at 2 – 100 microns
Space-based telescopes are needed to detect infrared (10 – 100 µm) radiation

(Exceptio:n 10-25 µm range with 10m-class telescopes built in the 1990s – but it is still tough)

- Observed the sky at 12, 25, 60, 100 microns
- Emission from dust
- Revealed imbedded star formation
- And…

Orion Star Formation Regions

Andromeda Galaxy (M 31)
... Some other, unknown sources.

IRAS – 60 micron images
Optical follow-up revealed a population of infrared bright, interacting galaxies
How do we know that they are interacting/merging?
Why were these galaxies easy for IRAS to detect?

![Graph showing energy vs. wavelength for different types of galaxies.](image-url)
• Dust is Efficient at Absorbing Ultraviolet & Optical Light
• Optical Light from Embedded Stars is Absorbed by Dust and Reradiated as Infrared Light.
• But Infrared Light from this Warm Dust has a much Higher Chance of Escaping.
Molecular gas in a nearby spiral galaxy – star formation rate: few solar masses/year
Compression of gas in merger = star formation

2. Gas Only
Molecular gas in infrared galaxies. SFR = 100
Solar masses/year

1000 light years
Star formation signatures also seen in optical spectroscopy

Produced by gas heated by young stars
Late 1980s: … But often, Quasar-like signatures are seen in spectra…

- … And bright, compact Quasar-like nuclei
- … And a few Quasars have distorted host galaxies
- … And many nearby Quasars were detected by IRAS
- … And Quasars are about as common as the intrinsically brightest IRAS galaxies

Maybe the intrinsically brightest IRAS galaxy mergers evolve into quasars
The Model

**Progenitors**

**Merger phase**
- Gas compression
- Star formation
- Black hole fueling/building

**Quasar phase**

**Elliptical**

Time

100 million years

1 billion years
Do stars or Quasars energize bright infrared galaxies? Problem – Dust.

• **Optical light** from the center of the galaxy does not escape the galaxy, but optical light from stars in the outer galaxy can.
The effects of dust.

Ultraviolet
(0.1-0.2 \(\mu m\))

Near-Infrared
(1 – 2 \(\mu m\))

(Note: Optical = 0.55 \(\mu m\))

Thus, Quasars can hide beneath the dust.
1990s – Probing Infrared Galaxies in the Near-infrared

- Less susceptible to absorption by dust (10,000 times less likely to be absorbed by dust than optical light)
- Accessible from ground and space-based telescopes
- Can get high-resolution (~ wavelength/telescope diameter) images at near-infrared wavelengths
Addressing the Infrared Galaxy – Quasar Connection with **Near-Infrared** Observations

- **Approach 1** – **Near-infrared** (1 – 2 μm) imaging of infrared bright galaxies to look for bright, compact nuclei.

- **Approach 2** – **Near-infrared** spectroscopy of infrared-bright galaxies to look for Quasar-like gas heating.
High-Resolution Imaging of galaxies

Mauna Kea Observatories, Hawaii (14,000 ft)

Hubble Space Telescope

- To get clear images, we go to space, or we go to a high mountaintop.
- Why? To lessen the blurring effects of the dense atmosphere.
A1 – Imaging of Infrared Galaxies using the Hubble Space Telescope Near-Infrared Camera

Quasar-Like nucleus

Extended distribution of star clusters
HST Data – Infrared Galaxies

- Inner spirals
- Lots of star clusters
- Embedded compact nuclei
But only about 35% have bright, Quasar-like nuclei
A2 – Ground-based **Near-infrared** Spectroscopy of IRAS Galaxies

[Diagram showing gas, black hole, stars, and flux vs. wavelength graphs.]
Near Infrared Spectroscopy - About 30% show evidence of Quasar-like gas heating
Conclusions – 1990s

- Maybe only some of the brightest infrared galaxies evolve into Quasars.
- Maybe the brightest infrared galaxies only spend the last 30-35% of their lives feeding the black hole.
- Maybe the Quasars are buried too deep in the dust to be accessible at near-infrared wavelengths.
Late 1990s – 2010

- **X-rays** – some observations of Infrared Galaxies with X-ray satellites have already shown evidence of dust covered Quasars in objects that do not look like Quasars even in the near-infrared.
SIRTF will probe deep into the dusty regions of galaxies.
Half of the energy emitted since the Big Bang is observed at infrared wavelengths.